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Review Article

# Bits and Bytes in Soft Tissue Management Around Teeth and Implants: Revisiting Procedures in the Digital Era

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**Received:** June 16, 2023; **Published:** June 30, 2023

## Abstract

The scope of this paper is to review novel workflows around well-established procedures involving soft tissue management in the fields of Periodontology and Implantology. Available technological advances, both in software and in hardware, allow for more powerful computational models, some employing even AI. These new tools can be used to achieve better and more predictable results in various procedures. Amongst the many procedures enhanced by this new digital revolution we will revisit crown lengthening procedures, soft tissue adaptation and manipulation around dental implants, periodontal defect detection and the use of mathematical models to create better pre-shaped soft tissue substitute grafts. All the above procedures can be enhanced by current digital tools. It is worth noting that the constant increase in computer power allows in its turn more advanced and complex software which changes dramatically how we perceive and address these procedures.

***Keywords:*** *Digital; Soft Tissue; Periodontology; Implants; Digital Dentistry; Crown Lengthening; Smile Design; CBCT*

## Abbreviations

CBCT: Cone Beam Computed Tomography; CAD: Computer Aided Design; CAM: Computer Aided Manufacturing; CAIS: Computer Aided Implant Surgery; CADx: Computer Aided Diagnosis; AI: Artificial Intelligence; EGD: Excessive Gingival Display; AAE: Altered Active Eruption; VME: Vertical Maxillary Excess; CEJ: Cemento-Enamel Junction; STS: Soft Tissue Substitute Grafts; SCGT: Subepithelial Connective Tissue Graft; GTR: Guided Tissue Regeneration; CHA: Customized Healing Abutment; DICOM: Digital Imaging and Communications in Medicine

## Introduction

The digital revolution is an undeniable fact. It has affected the way we perceive the world around us, the way we communicate, we travel, we interact socially [1]. So, it is only natural and expected that this revolution would find its place into various aspects of healthcare -including dentistry. With the advent of Cone Beam Computed Tomography (CBCT) technology and the subsequent digitalization of implant dentistry, Prosthodontics took the lead with Computer Aided Design/Computer Aided Manufacturing Systems (CAD/CAM), and then Implantology followed suit, using Computer Guided Implant Surgery (CAIS). At present complex computer software, supported by ever more powerful hardware, is taking the lead with the newly launched Computer Aided Diagnosis (CADx) [2-5], changing forever the way healthcare is implemented. Augmented and Virtual Reality are already modalities used in training the current and future generations of dentists [6].

But beyond these well-established advances in dentistry utilizing digital technology, what has been achieved in the fields of Periodontology and especially soft tissue management, using the available digital tools at hand? How has this affected our everyday workflows has it created better conditions for our patients or more predictable results? Especially now that patients are ever more demanding and expecting high esthetic results [7]. The scope of this review is to lose a dad whether this is. How has this affected daily workflows? Has it created better conditions for patients or more predictable results? The scope of this review is to elucidate whether the use of digital technology is a viable option for today's dentist or merely a herald of advances to expect in the future.

## Computer applications in dentistry

Technology is advancing by leaps and bounds. The amount of memory of a mobile handheld device, such as our smartphone, is multiple of that used by the first Supercomputers a few decades ago. We are experiencing the advent of the Digital Revolution and the digitalized network society [1], which is widely affecting how we operate as individuals and as a consequence as dental professionals.

Moore's Law states that the number of transistors on a chip doubles every 24 months [8]. This is based on an empirical observation, yet it denotes the current rate of advances that we get to experience. More advanced computers give us access to more computational power, which in turn, allows for Deep Learning techniques and Artificial Intelligence (AI) [9]. Computers help us diagnose by segmenting and analyzing radiographs [5] by comparing radiographs to assess bone loss [4], by helping us design a new smile for our patients [10-12]. For the purpose of this paper, we will focus on computer applications in the fields of Periodontology and Dental Implantology and specifically those that affect soft and hard tissues.

## Computer applications in periodontology and implantology

### Surgical guides for crown lengthening procedures

Excessive display of gingival tissue (EGD) is an esthetically displeasing, non-pathological condition affecting many patients [13]. Several conditions may be contributing to this, such as altered passive eruption (APE), altered active eruption (AAE) vertical maxillary excess (VME), a short or hyperactive upper lip [14]. Altered passive eruption occurs when the teeth become fully functional and achieve contact with the opposite occlusal plane, while the process of passive eruption from the dentoalveolar process has not been fully achieved. In altered active eruption, the teeth achieve contact prematurely and thus they have not reupped properly, thus the osseous crest is very close to the cemento-enamel junction (CEJ). In both modes of alteration of the eruption process, the gingival margin and sometimes the bone has not receded to its proper position, thus being more coronally than normal. This can lead to EGD [15].

The treatment of choice of this condition is surgical crown lengthening [16]. This is one of the most common surgical procedures [17] aiming not only to correct the esthetic disharmony [18] but also to re-establish the biologic width [19] in a more suitable and apical position.

New studies suggest the use of CBCT data in order properly diagnose and plan such a case [20-23]. The suggested method starts by having a detailed CBCT of the patients' dentition while retracting the lips so that there is no interference to the measurements buy the lip soft tissue [24]. On the CBCT the clinician can measure the exact position of the CEJ, the position of the gingival margin and the position of the osseous crest [24,25]. These measurements can be performed in a completely non-invasive manner in stark contrast to sounding, which was the previously technique of choice for this purpose. Moreover accuracy - although dependent on the CBCT specifications and Voxel resolution - is increased [26]. Tissue thickness can be measured [27] and the tissue type and gingival phenotype can be assessed and properly considered when planning such a case as it has been documented that thicker tissue will exhibit some rebound over the next 6 to

12 months [28,29]. A surgical guide [30,31] (Figure 1) will be then designed with the help of suitable CAD software and produced either by milling or by more conveniently 3D-printing. In some cases, according to a modified workflow, a double surgical guide [21,32] - one for the soft tissue excision and one for the bone resection - is created.

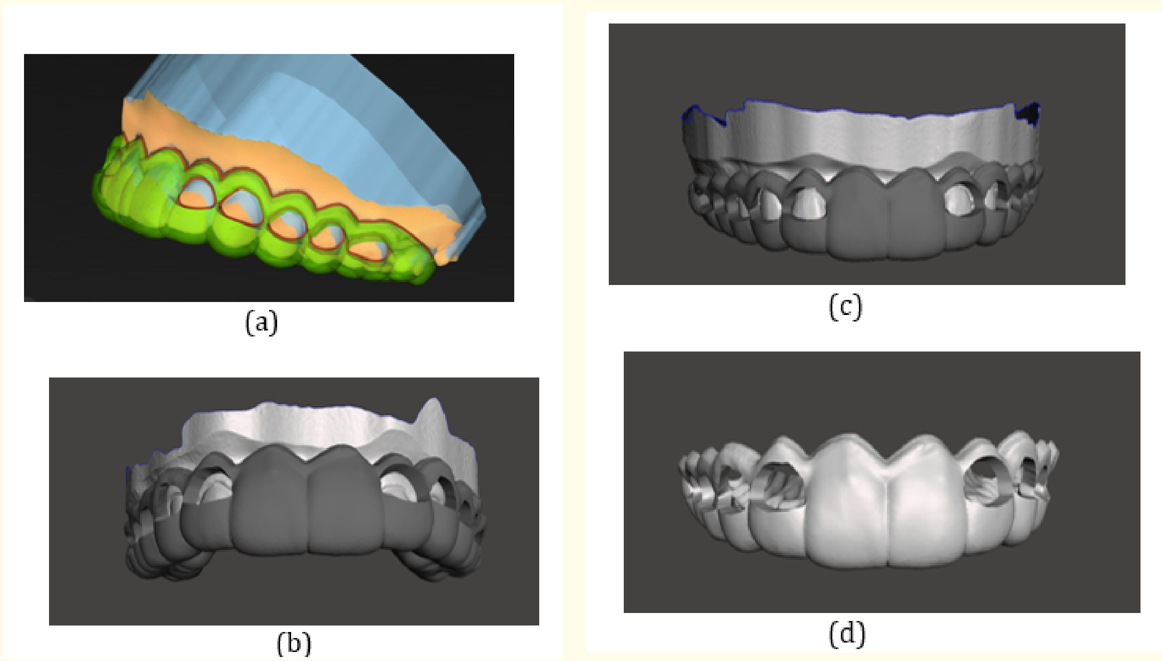



***Figure 1:*** *Creation of surgical crown lengthening guide - case from author's archive: (a) Surgical guide design in inLab® v22.0.1 (Dentsply Sirona GmbH, Bensheim, Germany) CAD software; (b) Surgical guide fitted on the wax-up model; (c) Surgical guide fitted on the actual pre-op model; (d) Anterior view of the guide.*

These guides are used during surgery to predictably and accurately remove tissues, thus helping us execute the proposed treatment plan and fulfill our patients' esthetic expectations. One study suggested taking this workflow one step ahead and creating multifunctional anatomical prototypes in the form of 3D-printed templates that could be used for patient communication before the procedure but also to validate its accuracy after a sufficient healing period [23].

However, it is quite different when the case at hand features a mixed dentition with implants and natural teeth. In such a case it is evident that we cannot crown lengthen the implant but at best change the abutment height and re-contour the tissues using a new temporary crown [33]. Also, we must consider the differences between the supercrestal soft-tissue compartments between teeth and implants when assessing and designing such a case [34]. It is notable that even these more complex cases, can be successfully and predictably treated, using this technology [35]. Also such guides have been used successfully when placing implants while performing a crown lightening procedure at the same time [36] which a demanding clinical procedure even for very skilled clinicians.

## Soft tissue grafts

Soft tissue defects, especially around implants can be very challenging but also very rewarding as it can directly affect and enhance the outcome of the implant rehabilitation [37]. The current gold standard for soft-tissue augmentation, where the goal is to increase the volume of available tissue, is to use a sub-epithelial connective tissue graft (SCGT) [38,39]. However these procedures entail the use of a suitable donor site [40], which adds to the morbidity of the procedure by introducing a second surgical site and thus a second wound.

In order to circumvent this problem research has provided us with suitable biomaterials that can be used instead of a SCGT. These are Soft-Tissue Substitute Grafts (STS). Several materials have been produced up today either allogenic, xenogenic or completely synthetic [41]. Using such a material provides us with an endless supply of grafts so we do not have to consider patient donor tissue availability and anatomical factors that might reduce this. It and alleviates patient pain and discomfort significantly [42]. However, their use is not widespread because of cost which is added to the overall cost of the procedure, the relatively poorer outcomes and the fact that they come in predetermined shapes and size. The latter creates the need for extensive modification of the graft while performing the surgical procedure [43]. This increases surgical time, patient discomfort and risk of infection [42].

By using the available digital tools complex mathematical models have been employed to assess the mean and median size, shape, thickness and overall dimensions of STS and help create pre-shaped graft materials that fit most of the defects with a minimal amount of modification. In this way there is considerable benefit for both the patient and the clinician as clinical time is dramatically reduced and accordingly we have reduced patient discomfort and risk of infection [44,45]. This group used a 3D scanner to scan models of the defects and by using a suitable CAD software created grafts that fit the site according to the specified protocols [39,43]. Then the digitally created graft was exported and mathematically analyzed in all dimensions. The outcome of this analysis was a database with the common shape and size of grafts designed to perfectly fit and correct these defects. Obviously, all defects are not the same and their shape and overall dimensions differ, but by creating STSs that are of mean shape and size, and maybe having some alternative configurations available, provides the clinical STS that will need minimal adaptation, once the appropriate configuration is selected. This ultimately reflects in reduced clinical time, better adaptation and overall, possibly better outcomes. At this point the above are not commercially available, however, they show the trend of things to expecting the near future.

## Diagnosis of periodontal defects

The gold standard in Periodontal examinations is using a suitable periodontal probe in order to properly measure and log clinical attachment and loss of it, if applicable [46]. The latter are supplemented by dental radiography - periapical films and orthopantomograms - in order to get a detailed view of osseous levels. Furthermore, we are interested in the morphology and detail geometry of periodontal defects as this is extremely important in order to regenerate them predictably by using the correct protocol [47-49].

The use of CBCT can enhance our abilities in properly detecting and measuring such defects. Perhaps the most interesting part would be assessing the geometry and dimensions of infrabony defects. Current literature, through systematic reviews [49] has made it clear that wide defects are more suitable for Guided Tissue Regeneration (GTR) using a combination of bone graft and a collagen membrane to cover the defect. On the other hand narrow and deep defects are more amenable to using amelogenin (Emdogain® - Straumann Group, Basel, Switzerland) to properly address the issue [50]. Measuring the defect using a periodontal probe - although indispensable for now - can be quite challenging. The shape and size of the crown, the location of the defector even the presence of granulation tissue lining the pocket can lead to underestimation of the defect dimensions and especially its depth. Of course, all these become apparent once the flaps have been raised but, in this time, and day, clinicians want to be as much prepared as possible before the procedure is initiated. The relative accuracy of CBCT can be used to give us a quite detailed outlook of the defect in question [26]. Another added benefit when comparing use of CBCT data analyzed by software in contrast to typical radiographical data is the ability to diagnose defects on the buccal and lingual aspects where classic radiograph is limited by object superimposition.

Another study [51] suggested the use of CBCT data to detect dehiscences and fenestrations. Dehiscences and fenestrations can occur naturally but are considered more prevalent in patients exhibiting Class I Malocclusion with moderate anterior crowding. If during orthodontic movement the tooth is moved beyond the osseous envelope of the alveolar process, then a dehiscence or fenestration may develop or a pre-existing one may deteriorate. Presence of dehiscence is also highly correlated with gingival recession and the associated problems.

The study group were patients that would be having orthodontic treatment for Class I malocclusion. The results were validated by means of surgical exposure of the sites in question, as was required per the protocol for periodontally accelerated osteogenic orthodontics [52] that was used to treat these patients The results showed two-and-a-half times greater proportion of dehiscences being diagnosed using CBCT data in contrast to direct examination. When comparing fenestrations, the proportion was almost three times more being diagnose using CBCT data. However, the linear measurements of the defects were slightly overestimated when using the CBCT data. This shows a clear advantage of the use of Digital CBCT data in order to properly diagnose such defects before the surgical exposure of the area.

### Soft tissue manipulation using customized healing abutments

The importance of emergence profile of a dental implant is well established. Not only can it enhance the esthetics of the restoration - making it appear to emerge from the soft tissue rather than overlap the soft tissue - but it also is important in terms of soft tissue stability and hygiene management [53]. The proper management of the emergence profile is achieved by careful planning at various stages along the course of implant therapy. Undoubtably, the first stage would be appropriate placement of the implant in a 3D space that allows for non-complex implant restoration. Implant depth, angulation and overall position should be optimal. Digital planning and CAIS are invaluable tools in order to achieve this [54] (Figure 2).

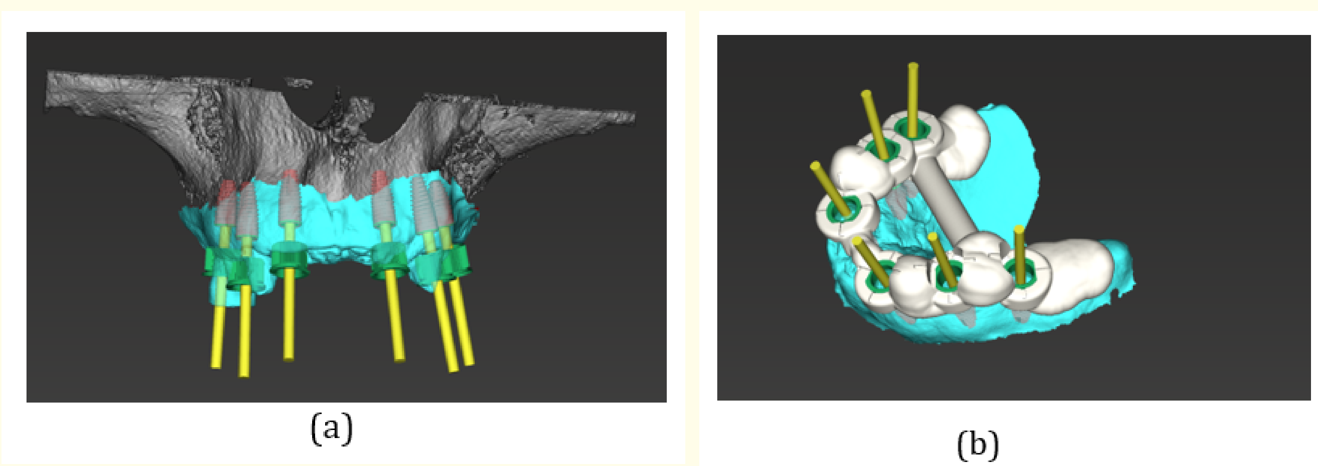
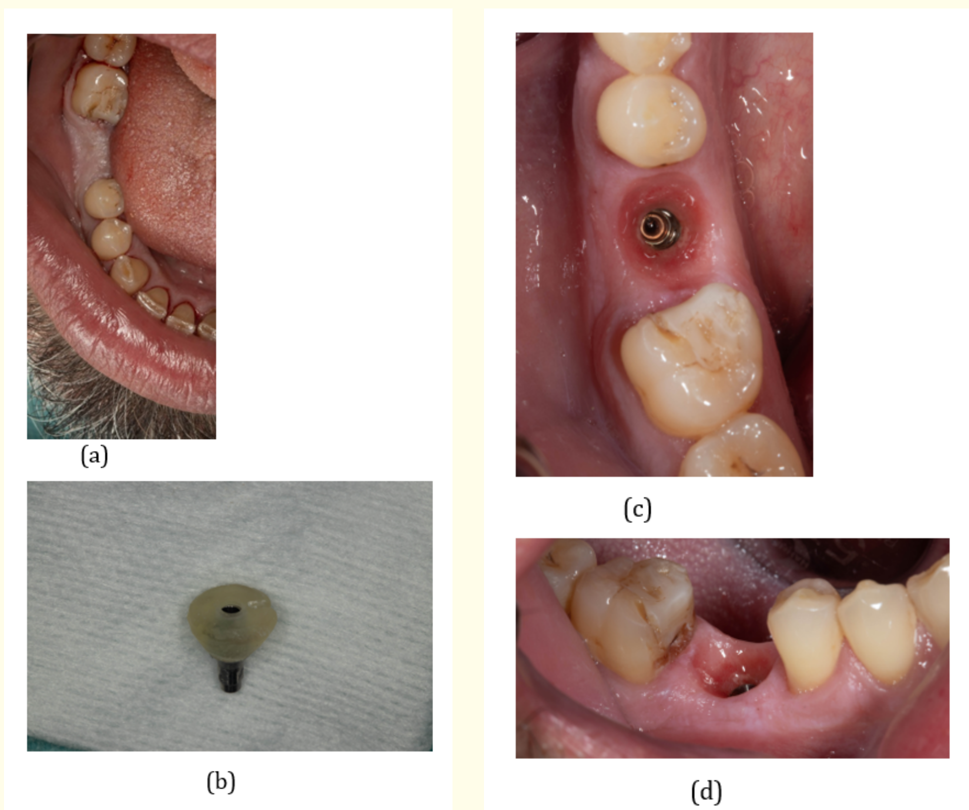



***Figure 2:*** *Digital planning tools for computer aided implant surgery (Co-DiagnostiX®, Dental Wings, Straumann Group, Basel, Switzerland): (a) Implant placement outlook; (b) Designed surgical guide ready to be exported for 3D-printing (from author's personal archive).*

But once we have a fixture in place, at the correct 3-D-position several steps should be undertaken - at soft tissue level - in order to achieve this optimal emergence profile. It is well known that an interim restoration should be placed in order to carefully shape the gingival tissues and optimize esthetics [33], especially in the critical anterior zone. However, current available digital tools offer us elegant ways to pre-shape the tissues and make this conditioning easier, more predictable and faster. Moreover, this can be readily applied to the posterior area, where immediate loading or immediate provisionalization is not usually the case, nor it is required.

Based on the above, it is evident that the available healing abutments which come in pre-defined shaped, and sizes are not ideal for the task at hand. Their goal is to create a transmucosal access to the implant interface through which impression, connection of a prefabricated abutment and of the associated prosthesis can be achieved. But their potential ends here. If we want to shape the tissues properly then an interim prosthesis should be fabricated, and we need to go through a long process of selectively adding or subtracting resin material in order to create the necessary emergence profile. CBCT data has been employed to create - based on the teeth dimensions - ideal and custom healing abutments (CHA) that can be attached on implant placement [55]. This in turn can allow for soft tissue healing while being adapted to the shape of an ideal emergence profile that will host and support the restoration to be fabricated. Once appropriate healing time has elapsed and the implant is ready for restoration and loading, the detailed shape of the already formed emergence profile can be transferred while scanning to the design software. In this way the information is not lost but rather used in a significant way to help the software shape a proper restoration that would take into consideration the emergence profile already created. Thus, the fit of the restoration with the underlying soft tissue is enhanced (Figure 3).



(e)

(f)

***Figure 3:*** *Restoration of missing #46 with an implant placed with a digitally designed surgical guide and forming the emergence profile by use of a customized 3D-printed healing abutment; (a) Initial presentation; (b) 3D-printed custom healing abutment; (c) Emergence profile after 8 weeks (occlusal view); (d) Emergence profile after 8 weeks (buccal view); (f) Final restoration in place CAD/CAM Monolithic Zr Crown; (f) Final Restoration buccal view (Case from author's personal archive).*

Other papers [56] have detailed protocols where a pre-determined shape is used as the basis of a custom healing abutment. This is then modified chairside to better fit the site and adapt the soft tissues. As a protocol it may involve more manual adjustments but allows for less time to be spent pre-operatively in order to design the abutment. An interesting concept is that of designing and delivering a socket sealing abutment (SSA) [57]. This is a custom healing abutment designed with the help of an impression taken after extraction and implant placement - in this paper at molar sites - to allow for socket sealing, a better patient experience and formation of a more favorable emergence profile.

This concept is effectively a protocol where the selection of the appropriate emergence profile starts immediately with the implant placement, even in posterior areas [58]. The implant is scanned using an IOS at the time of surgery and an ideal crown is designed at that stage. The crown can be milled from a composite-infiltrated ceramic and placed as an immediate restoration, guiding the tissues in full adaptation and acting as a customized healing abutment.

The "Digital Flip Technique" uses the shape of the contralateral tooth - if present - as a template to create the ideal emergence profile. The scan is superimposed on the Digital Imaging and Communications in Medicine (DICOM) Data in specialized design software and the contralateral tooth is mirrored to help shape a CAD/CAM fabricated custom healing abutment which is then cemented on to a standard titanium base [59]. In this way the authors created a healing abutment mimicking the shape of the missing tooth and shaped the tissues for the ideal emergence profile.

In a variation of this protocol [60], the crown created is the separated digitally in a coronal and apical part at a level inclusive of the mesial and distal contact points. The apical part is milled or 3D-printed and can be cemented to a titanium base creating a CHA. The latter is then screwed onto the implant, the contact point pressure is assessed and corrected if necessary and the respective soft tissues are sutured around it. After healing and when the implant is ready to be loaded the at-the-time-of-surgery designed crown can be milled and delivered. As the emergence profile is already adapted to the milled crown by means of the CHA placed through the healing period, the tissue needs no additional manipulation and causes no discomfort to the patient. Moreover, contact points have been established and remain stable, thus adjusting the restoration is trivial. In some cases, minor occlusal adjustments may be necessary.

All the above techniques allow for unforced soft tissue adaptation to a predetermined shape of an ideally designed crown. They also maintain stable contact points. By having all this information collected at the time of implant placement and by supporting and gently shaping through healing the underlying soft tissues, the definitive restoration can be delivered effortlessly, with minimal or even on adjustments necessary [61]. This is extremely time efficient and allows for the patient to have a comfortable experience throughout the implant therapy. This type of modified abutment does not cause any additional inflammatory stress to the implant site, compared to prefabricated healing abutments [62]. It also helps preserve marginal bone integrity [63].

The above workflow can be coupled with CAIS where the proper position of the implant is determined pre-surgically. These software suites allow us to export the implant position to the respective CAD software to design the implant crown before the implant placement. In this way everything is accomplished pre-surgically. However, we need to take into careful consideration the accuracy of the implant placement through this method and allow for certain inaccuracies that will inadvertently be introduced to our workflow. That is way the suggestion is to scan again at implant placement in order to have the most accurate impression of the condition at hand.

## Discussion and Conclusion

It is apparent that digital applications in dentistry are here to stay. Judging from the number of dental subfields where we encounter such applications and by their relative scope, it is not the future but a rather exciting present. We as dentists have the unique opportunity to utilize computer systems in order to make more predictable treatment for our patients and achieve more predictable results. The exponential increase in computer power allows for ever more complex computer software to be created. This in turn can allow for AI to be incorporated in the latest implementation of software suites, making workflows not only more efficient but also more accurate. Let us also not forget that many Dental Practices now host specialized equipment that is not within the boundaries of what we perceived as 'Dental Clinic Necessary Equipment", such as intraoral or even face scanners, 3D-printers, milling machines and powerful CAD workstations. This is indicative of the shift towards "Digital Dentistry" and its many applications, which takes in increasingly larger share of the procedures performed in practices worldwide.

Crown lengthening is a procedure that is performed daily by numerous dental practitioners. With the exponential increase in patients demand for aesthetic rehabilitations, crown lengthening procedures are an integral part of the new "Smile Design" torrent that sweeps dental practices. The creation of a guide, by use of a smile design software suite or equivalent CAD based software allows for greater accuracy in the execution of the tissue removal, and ultimately an easier and quicker surgical procedure. The fact that many such suites allow for data transfer between the "Smile Design" software, where the "Ideal Smile" is created, and the CAD software or module for guide design is an additional benefit contributing to the success and predictability of the outcome.

The wealth of data we can harvest from today's CBCT technology can also be used to properly and predictably measure periodontal defects. Conventional dental radiography is limited by 2D images where superimposition of structures can lead to missing vital information. Information that can be effectively used for a proper diagnosis and better treatment planning for our patient. That could be selecting the most appropriate surgical procedure or graft material for the case in question. The advent of 3D imaging solutions gives us undoubtably a superior understanding of the specific defect geometry of an infrabony defect and the accurate linear measurements provided can be of extreme importance in the decision-making process. Again, the relative risks should be weight here. CBCT is exposing patients to far greater radiation dose, although newest machines offer ever reducing dosage. Selective use of the technology - as always - and low dose programs should be used in order to strike a balance between risks and benefits.

The increase of computer power is nowhere more at play than the sweep of AI in all fields. Complex mathematical models allow for deep learning and software suites that present such abilities can be found more and more these days. Such complex models can present to use the ideal mean shape and overall dimensions of a pre-formed STS. Having such a graft, or rather a small variety of such grafts that would fit several strategic and areas-specific defects, such as anterior, posterior, interdental etc., could prove to be revolutionary. The time savings and simplicity of use would make the latter appear invaluable, especially if we take into consideration that we do not need donor surgical site, thus reducing patient morbidity. This could potentially change commercial trends regarding use and adaptation of STSs, which is still low today. The latter, in turn could through increased funding, lead to the creation of STSs with superior handling and regenerative capabilities, which still is an issue as the lack behind the gold standard which is native connective tissue grafts.

One ever-promising field is implantology where the digital technology has perhaps the most widespread effect. This of course is CAIS, which has completely revolutionized implant dentistry. This is widely known and not within the scopes of this review. However, we cannot forget the impact of soft tissue manipulation on a successful implant restoration. The importance of the emergence profile, both for the esthetics and for the hygiene and maintenance of the restoration is well established. Traditional shaping would take a few weeks or even months as tissues lose their original architecture because of the implant placement surgery and the use of a rather universal healing abutment. The use of this technology can help us shape the tissues in a very predictable manner. Databases have been created with ideal shapes and emergence profiles for various teeth. This coupled with the availability of 3D-printing can give us easy tools to help shape tissues starting right from the implant placement - or implant uncover - surgery. Staring so early benefits both the clinician and the patient. The clinician has better control of the process as there is ability of intervention at any point in time throughout this period. Composite resin can be readily added to the customized healing abutment, or printed material can be removed through the use of regular dental equipment. Also, the tissue manipulation potential at the time of surgery is greater because healing can happen around the customized abutment and the tissue do not suffer from undue pressure that could risk damage or even necrosis. It is also considerably less disruptive for the patient as there is no discomfort. The formulated tissues with the ideal emergence profile in situ, can be scanned using an IOS and all the information of the gingival architecture can be passed on to the software that will take these into account when designing the proper restoration. The presented workflow is elegantly creating the necessary shape of soft tissues to support a natural-looking restoration, while creating conditions necessary for the long stability and longevity of the implant restoration.

As a footnote we must also discuss about the pitfalls and limitations these workflows. The first would be financial burden. These workflows need specialized software and hardware, be-it CAD workstations, IOS, milling machines. All of these - although prices have reduced overtime - are still quite expensive. Moreover, there is the financial burden of proper training on these. This costs money and time. So, one solution would be outsourcing these services. There are already many freelance digital designers, offering their services, or even companies that offer complete solutions such as designing a surgical guide and producing it so that the dentist receives the finished product. That simplifies everything at a cost which is usually low and presents itself as a valid solution for a practice not heavily invested in such technology or not having enough cases to warrant such an investment. Another point of paramount importance - and one that tends to be easily overlooked - is the fact that before we venture in such procedures the clinician should be comfortable with executing these in the "analog" manner. All designs have failures, and all guides may break. Should such an unfortunate incident take place while performing the procedure, the surgeon should have all the knowledge and experience to finish the procedure without the help of these digital enhancements. Our patients interest comes first, and all procedures should be designed to be effective, predictable and above all safe for our patients.

## Conflict of Interest

The author declares no conflict of interest.

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**Volume 22 Issue 7 July 2023**